Homework11

Problem 1 Resonant cavity

A resonant cavity of the form illustrated in Fig. 1 is an essential part of many microwave oscillators. It can be regarded as a simple LC circuit. The inductance is that of a rectangular toroid with one turn; (using the results in Lec 13-4). This inductor is connected directly to a parallel-plate capacitor ($s \ll h$). Find an expression for the resonant frequency of this circuit, and show by a rough sketch the configuration of the magnetic and electric fields.

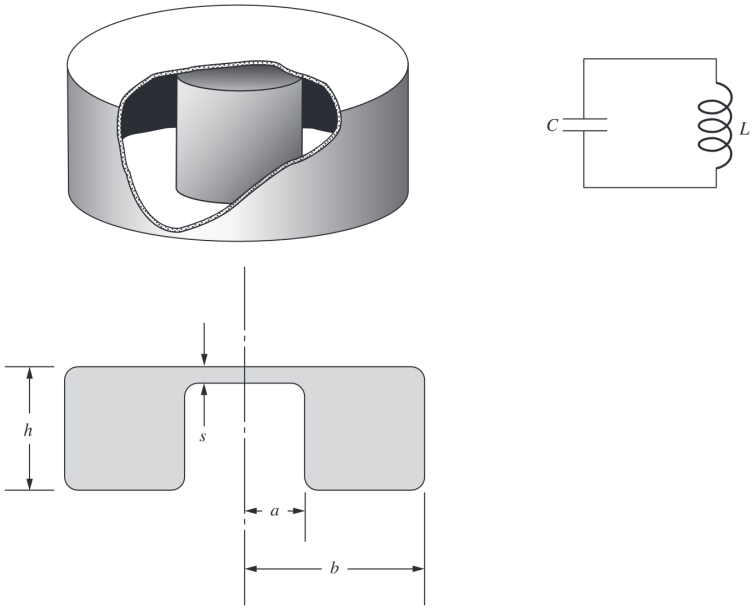

Fig 1

Problem 2 Polarized water

The electric dipole moment of the water molecule is given in Fig. 2 ($6.13 \times 10^{-31}\ \mathrm{C \cdot m}$). Imagine that all the molecular dipoles in a cup of water could be made to point down. Calculate the magnitude of the resulting surface charge density at the upper water surface, and express it in electrons per square centimeter.

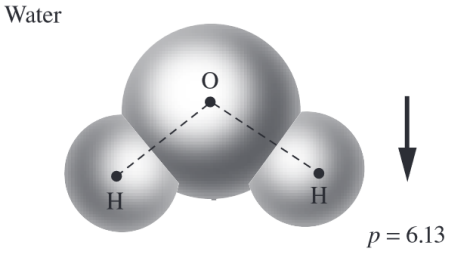

Fig 2

Problem 3 Partially filled capacitors

Figure 3 shows three capacitors of the same area and plate separation. Call the capacitance of the vacuum capacitor C_0. Each of the others is half-filled with a dielectric, with the same relative permittivity ϵ_r, but differently disposed, as shown. Find the capacitance of each of these two capacitors. (Neglect

edge effects.)

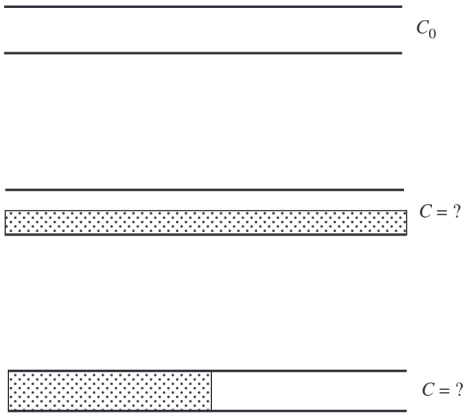

Fig 3

Problem 4 Force from an induced dipole

Between any ion and any neutral atom there is a force that arises as follows. The electric field of the ion polarizes the atom; the field of that induced dipole reacts on the ion. Show that this force is always attractive, and that it varies with the inverse fifth power of the distance of separation r. Derive an expression for the associated potential energy, with zero energy corresponding to infinite separation. For what distance r does this potential energy have the same magnitude as $k_B T$ at room temperature (which is $4 \cdot 10^{-21}$ joule) if the ion is singly charged and the atom is a sodium atom (with **Polarizability**, $\alpha = 108\pi \times 10^{-30}\ \mathrm{m}^3$)?